

## SHORT COMMUNICATION

### Movement and diet of domestic cats on Stewart Island/Rakiura, New Zealand

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**Abstract:** Domestic cats (*Felis catus*) in Halfmoon Bay, Stewart Island/Rakiura, were tracked to assess the potential for incursions into native forest around the township, and into Rakiura National Park c. 5 km away. During February and April 2005, 15 and 4 radio-collared cats were tracked, respectively. During a six-month period, cat-owners logged prey brought home by 11 cats. Cats were at home >90% of the time. Of the six cats that left home, movements were small: home range was between 0.05 and 16.6 ha (100% minimum convex polygon). Four cats brought prey home, comprising rats (*Rattus* spp.; 67% of prey items), and birds (four species, one native; 33%). Cats sampled at Halfmoon Bay were unlikely to enter the national park; however, many locations were within native forest patches, indicating that native birds within Halfmoon Bay were vulnerable to predation. The high proportion of rats caught could have benefits for native species.

**Keywords:** *Felis catus*; home range; prey; spatial ecology; Stewart Island; subsidised predator

## Introduction

There is a mounting body of evidence indicating that domestic cats (*Felis catus*) are significant predators of wildlife in urban and rural areas (Churcher & Lawton 1987; Fitzgerald 1988; Barratt 1997a; Gillies & Clout 2003; Woods et al. 2003; Baker et al. 2008; Morgan et al. 2009; van Heezik et al. 2010; Loss et al. 2013). The extent of their impact is likely to depend on the area over which they roam, their proclivity to hunt, and the species they encounter. Unlike feral cats, which cover extensive areas in search of primarily mammalian prey, and which are restricted in their numbers and movements by the availability of prey (Fitzgerald & Karl 1986; Harper 2005), domestic cats are fed by their owners. Thus home range size is much smaller than for feral cats, reflecting cat densities. Consequently, where densities are low in rural areas or on the urban fringe, cats have relatively large home ranges, but as human housing density increases, home range size becomes progressively smaller (Barratt 1997b; van Heezik et al. 2010; Metsers et al. 2010). Nevertheless, even within the same kind of habitat, home range size of domestic cats can be highly variable (Morgan et al. 2009; Metsers et al. 2010; van Heezik et al. 2010, but see Kays & DeWan 2004; Lilith et al. 2008).

Home ranges of cats living on the edge of residential areas usually encompass neighbouring rural or forested habitat and these cats can have impacts on native wildlife (Gillies 2007; Lilith et al. 2008; Tennent & Downs 2008; Metsers et al. 2010; Wierzbowska et al. 2012). This can be of particular concern if the cats live close to areas of high conservation value such as national parks. Some studies have shown very limited movement of domestic cats into adjoining wild areas (Kays & DeWan 2004; Gillies 2007), whereas others have shown significant penetration by cats into wildlands (Metsers et al. 2010; Wierzbowska et al. 2012). In Poland, cats living in households within and surrounding a 2200-ha park potentially

roamed throughout the entire park (Wierzbowska et al. 2012). In this study, we determine potential impacts of domestic cats living in and around a small settlement (Oban, Halfmoon Bay), located c. 5 km from the boundary of Rakiura National Park, which comprises most of the area of Stewart Island/Rakiura, in southern New Zealand. It is not known what proportion of the c. 168 households in Halfmoon Bay own cats, but if cat ownership in Halfmoon Bay is similar to that measured in other urban areas in New Zealand, then about 35% of households would be expected to own an average of 1.33 cats per household (van Heezik et al. 2010), and Halfmoon Bay would probably have about 78 domestic cats. We investigated whether home ranges of domestic cats extended as far as the national park boundary, and whether they included patches of native forest surrounding the township. We also determined the extent of predation by domestic cats on wildlife by documenting prey brought home by cats.

## Methods

Rakiura or Stewart Island (47° S, 168° E) is the smallest of the three main islands of New Zealand, situated c. 30 km south of the South Island. The total area of the island is 1680 km<sup>2</sup>. Around 85% of this is National Park, although the study site in and around the settlement of Oban in Halfmoon Bay is primarily residential.

### Recruitment of cats

In December 2004, information and survey sheets were given to each of the 168 households in Halfmoon Bay, asking if the householder owned cats and whether they would be willing to allow their cat(s) to participate in the radio-tracking study, prey survey study, or both. Further demographic details of any cats owned were requested, including age, sex, weight, and whether

the cat was neutered, and respondents were invited to return the form to the Department of Conservation (DOC), Stewart Island/Rakiura. Each cat owner who agreed to participate in the study was visited and asked a second set of survey questions concerning the behaviour and characteristics of their cat(s). Information collected included whether cats were free to go outside at night and whether a collar was worn (with or without a bell), indicating the potential for nocturnal movement and the ease of VHF collar use. Questions determining the availability of food and potential for opportunistic hunting were also asked, specifically regarding feeding regime (continuous or number of meals) and type of food provided.

Owners who agreed to participate in the prey survey recorded the species of every prey item that their cats brought home and the date caught between February and July 2005. If owners found it difficult to identify prey species they were asked to contact the Stewart Island DOC office so that accurate identification could be made.

### Radio-tracking protocol

Each study animal was fitted with a 48-g VHF radio collar (Sirtrack; Havelock North, New Zealand). Data were collected during 28 days from 15 cats between 1 and 28 February 2005 (i.e. during summer, when avian young were likely to be abundant), and subsequently on a subset of four of these cats (two females and two males) chosen according to their availability, for seven days from 13 to 19 April 2005, when temperatures were cooler. Locations from both periods were combined. Directional signals from each transmitter were obtained by a single trained observer, using a collapsible hand-held Yagi antenna (Sirtrack; Havelock North, New Zealand) and a portable receiver (Telonics TR4, U.S.A). Bearings were recorded from a hand-held compass. Cat locations were determined by triangulation of bearings using three to four different receiving locations per animal, or alternatively by homing in on the animal, followed by visual confirmation. Beacon tests for location error were conducted by taking repeated bearings ( $n = 6$ ) on transmitters in known outdoor locations under study conditions. Mean location accuracy was  $0.003 (\pm 0.85)$  ha, although triangulation on a moving animal is likely to have a larger error than on stationary radio collars.

Cats were radio tracked by collecting locations at discrete time intervals during night and day to create different sampling periods. Each study animal was located a minimum of 30 times during February, and a minimum of 20 times in April. Sequential locations on a given cat were at least 1 hour apart to avoid autocorrelation: within this time period the cats could have moved to any point within their home range.

### Data analysis

Home range size was estimated as 100% minimum convex polygons (MCPs) using Ranges 8 (Kenward et al. 2008). These were used because we wished to identify outer boundaries of movement, ensure that infrequent long distance movements were included in the home range, and allow comparisons with results from other studies. Incremental analysis was carried out in Ranges 8 to determine whether home ranges were fully revealed. Consecutive areas were plotted against the number of locations until there was evidence of stability, which indicated that adding further locations would not improve the home range estimate. Active cats were defined as those that were located away from home on at least three occasions. The home ranges of cats that were never located outside their owners'

properties were assigned the value 0.05 ha, which is at least as small as all properties.

Statistical tests were conducted using MINITAB v.14 with a significance level of 5%. Weight was not tested as a variable because many of the cat weights obtained were estimates provided by owners and therefore possibly inaccurate. Because we had a small sample of cats, we did not compare cats by age or sex, or between sampling periods.

## Results

### Participants

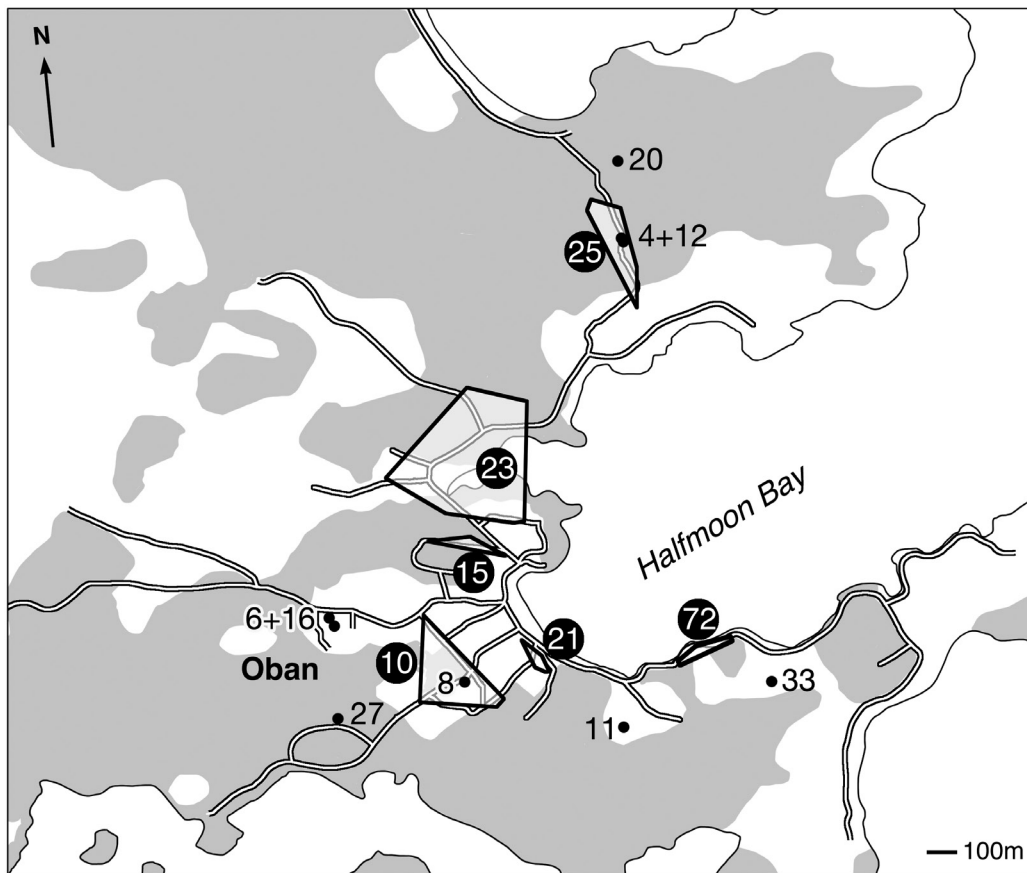
The survey yielded a low response, with only 17 (c. 7%) of 168 distributed surveys returned, and 11 owners willing to participate in both the prey item and radio-tracking studies. The total number of domestic house cats in Halfmoon Bay is unknown but estimated to be approximately 100 (BB, pers. obs.). Fifteen cats (9 neutered males, 1 unneutered male, and 5 spayed females) were followed, with three cats belonging to the same household (Table 1). All cats were healthy and in good condition. A total of 578 locations were collected from the 15 cats, with a mean of  $39 (\pm 11.0)$ .

### Home ranges

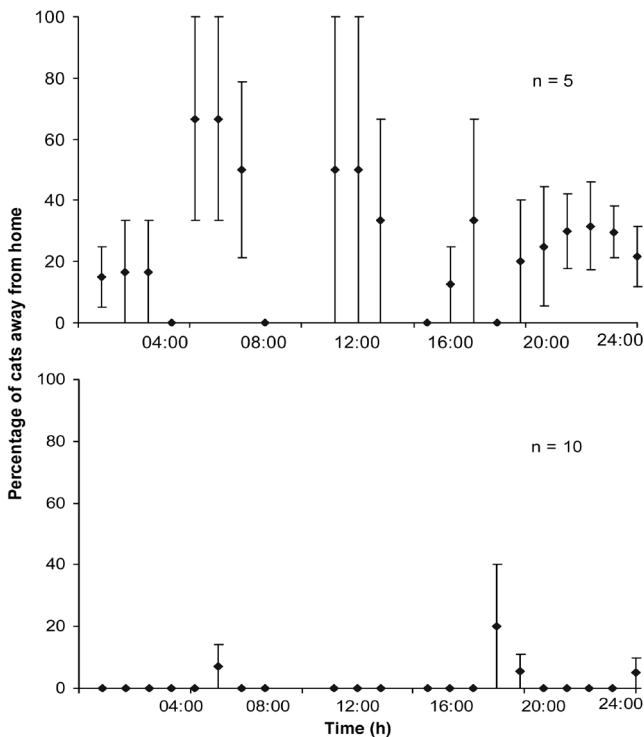
Incremental analyses indicated that home ranges were fully revealed only for cats that did not leave their home property during the tracking period, and the areas reported are therefore under-estimates. Home range size varied from 0.05 ha (an arbitrary value assigned to cats that never left their properties, denoting a typical property size including house and garden) to 16.58 ha (Table 1), with a median value of 0.05 ha, and a mean value of 1.74 ha ( $SD = 4.33$  ha). Only six cats moved away from their property, three of which had a home range greater than 1.5 ha: five of these were the youngest of the 15 sampled. Home ranges and locations of all cats are shown in Figure 1, indicating that all cats that moved outside their properties included areas of native forest in their home range.

**Table 1.** Home range area (ha), represented as 100% MCPs for 15 cats in Halfmoon Bay (Oban), Stewart Island/Rakiura during February and for four cats in April (indicated by an \*). Home ranges of 0.05 ha are an arbitrarily small value entered for cats which did not move out of their own property. † denotes three cats that were from the same household.

Cat I.D.	Sex	Age (yr)	Total number of fixes	100% MCP (ha)
04†	M	9	32	0.05
06	M	6	36	0.05
08	F	8	32	0.05
10	M	1.5	31	4.96
11	M	6	31	0.05
12†	M	8	60*	0.05
15	M	8	32	0.65
16	M	14	36	0.05
20	F	9	54*	0.05
21	F	1.5	31	0.34
22	F	9	31	0.05
23	M	5.5	54*	16.58
25†	F	2.5	54*	2.88
33	M	7	32	0.05
72	M	3	32	0.26



**Figure 1.** Home ranges of six cats in Halfmoon Bay (polygons). Black dots indicate the locations of homes of cats that never left their properties. Grey areas represent native vegetation cover (adapted from ArcMap 9.1). Numbers are cat ID numbers (see Table 1). Cats 4 and 12 were from the same home and are represented as a single black dot within the home range of cat 25, which was also from the same household.



**Figure 2.** Activity of 15 cats over 24 h during February and April in Halfmoon Bay, Stewart Island/Rakiura, indicated by the percentage of time spent away from home; active cats (top), non-active cats (bottom). Active cats are those that were located away from home more than twice. Standard error truncated at 0 and 100.

Active cats were defined as those that were located away from the property boundary on at least three occasions. Five of the 15 cats were likely to be located away any time of the day and night, except for short periods in the morning (between 0800 h and 1100 h) and afternoon (between 1400 h and 1600 h; Fig. 2). Activity peaked in the early morning (0500 h to 0700 h). Virtually all locations (90%) were obtained when cats were within their own property. Around 3% of fixes located cats at 50 m and 100 m from home and 10% of fixes located individuals 200–450 m away from their home. The furthest distance recorded for a single cat was 441 m.

**Prey reported**

During the six months of data collection, participating owners recorded a total of 27 prey items from four cats; the other 11 cats did not bring home any prey. A single cat brought home 63% of all recorded prey items (13 rats, three tom-tits *Petroica macrocephala*, and one blackbird *Turdus merula*), and the other 37% of prey comprised five rats, two house sparrows *Passer domesticus*, and three song thrushes *Turdus philomenus*. Rats (*Rattus* spp.) were the most frequently brought home prey item (67% of all prey brought home) and were caught by three of the four cats. The majority of the birds brought home were juveniles, with the exception of one adult blackbird. Tom-tits were the only native species brought back.

## Discussion

Despite being free to roam, the domestic cats we followed in Halfmoon Bay had small home ranges in February and April, averaging only 1.74 ha, with most cats rarely leaving their owners' properties. The largest home range was 17 ha, and the furthest away from home any of the cats were found was 441 m: all cats that left their properties moved through native forest situated close to where they lived. While the home ranges of the active cats were under-estimates of their true size, even with a doubling of home range size cats would not reach the national park. In the light of the evidence from other studies, and given that the township is about 5 km from the Rakiura National Park boundary, findings from the cats tracked in this study indicate that few, if any, cats in the township are likely to enter the national park frequently or regularly, although sampling of a larger number of cats throughout the year is necessary for greater certainty. Feral cats are certainly able to travel 5 km in a night (Recio et al. 2010), but domestic cats are less mobile. Metsers et al. (2010) recommended a cat-free buffer width of 2.4 km on the basis of domestic cat movements in a rural landscape, and Gillies (2007) tracked a single domestic cat based 1.2 km from a national park boundary and found that despite a home range of 11.7 ha it spent most of its time close to the house, at least during daytime when tracking was carried out, and did not enter the national park. The maximum distance from the house covered by domestic cats adjoining a national park in Poland was 1494 m (Wierzbowska et al. 2012).

Home ranges of Rakiura cats were smaller than those measured in suburban, urban fringe and rural habitats in other parts of New Zealand, and in Poland (Morgan et al. 2009; Metsers et al. 2010; van Heezik et al. 2010; Wierzbowska et al. 2012), similar to values calculated from owned cats in rural Illinois, USA (Horn et al. 2011), and larger than those recorded in New York State, which averaged only 0.24 ha (95% MCP; Kays & DeWan 2004). However, there were methodological differences between the studies that could account for some of the variation. Kays and DeWan (2004) located cats only during the day and used 95% MCPs, whereas this study located cats both day and night and used all locations to estimate MCPs. VHF radio tracking over relatively short time periods is likely to underestimate true home range size and this may have been the case in our study, although we followed the cats during at least a month, longer than some GPS studies (Metsers et al., 2010; van Heezik et al. 2010). Cats tracked by Metsers et al. (2010) and van Heezik et al. (2010) were wearing GPS collars that recorded locations every 15 minutes, providing more frequent and regular locations more likely to reveal the home range, but also more likely to provide biased results due to issues with signal acquisition under heavy forest cover. Wierzbowska et al. (2012) and Horn et al. (2011) used VHF collars, but over much longer periods (1 and 2–5 years, respectively).

Three cats in the study (20%) had home ranges greater than 2 ha, which included forested patches within the township. If the population of cats in Halfmoon Bay lies somewhere between an estimated 78 based on cat ownership elsewhere in New Zealand (van Heezik et al. 2010) and 100 (B.B. pers. obs.) and if about 20% of domestic cats frequently bring prey back home (van Heezik et al. 2010), there could be as many as 16–20 cats roaming throughout the forested areas in and around Halfmoon Bay, catching prey at least once a week.

Cats are known to be very individualistic in their hunting behaviour (Turner & Meister 1988; Fitzgerald & Turner 2000;

Loyd et al. 2013), but activity can be influenced by a number of factors (Mendl & Harcourt 1988). We found no distinctive patterns in movements during days and nights, except for some early morning activity and an increase in activity around midday. Adaptation by domestic cats to a human lifestyle may have caused cats to become more diurnal (Turner & Meister, 1988). Domestic cat activity can be influenced by weather (Goszczyński et al. 2009; Loyd et al. 2013) and feral cats on Stewart Island are more active in dry rather than wet weather (Harper 2007), but weather conditions (late summer in February and mid-autumn in April) were unlikely to have constrained movements of cats in this study. Movements of individual cats may also be shaped by territoriality or social contact with other domestic cats in Halfmoon Bay (Crowell-Davis et al. 2004), and possibly social interactions with feral cats in the forests around the urban areas (Harper 2007).

### Prey brought home

The proportion of cats in the study that did not bring home any prey (73%) was larger than has been reported in other urban areas (34%, van Heezik et al. 2010; 56%, Loyd et al. 2013; 60%, Baker et al. 2008), and the mean number of prey caught (1.8 in a 6-month period) was low compared with reports of 13.4 per annum (van Heezik et al. 2010) and 4.3–7.7 per annum in a more highly urbanised environment in Bristol, UK (Baker et al. 2008). The sample of cats followed in Halfmoon Bay may have been biased towards sedentary non-hunters, or it is possible that cat owners were not detecting or reporting all prey brought back. Only one native bird species was recorded, despite there being at least eight other native species in the area that cats have been recorded to catch at other localities (Harper 2009). While numbers of native birds brought back by cats were low, prey brought back can comprise as little as one quarter of what is actually killed (Loyd et al. 2013), and there may also be a bias in the species of prey the cat elects to bring home rather than consuming on site. Rats were taken by three of the four cats that brought prey home, and made up two-thirds of all prey recorded. Both ship rats (*Rattus rattus*) and Norway rats (*R. norvegicus*) are relatively common on Rakiura, and form the primary prey of feral cats on the island (Harper 2005). Given that rats are also significant predators of native wildlife, it is possible that cats may play an important role in controlling rat populations. However, the most active hunter in the study caught three native tomtits as well as 13 rats. The problem posed by rats has been recognised and a community group, The Stewart Island Environment Trust ([http://sircet.org.nz/Halfmoon\\_Bay\\_Project.php](http://sircet.org.nz/Halfmoon_Bay_Project.php)), is undertaking rodent control throughout the Halfmoon Bay area.

## Conclusions

While there was no indication that domestic cats in the township were visiting the national park, domestic cats frequented native forested areas in and around the township. Home ranges were very small compared with those in other studies, especially given the small size of the settlement and availability of open spaces. Although the predation of vulnerable native species, such as tomtits, suggests cats have the potential to negatively affect populations of birds in and around Halfmoon Bay, the role of domestic cats as predators of rats, which are also significant predators of birds, may be important in reducing overall predation of native species.

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